

# JES from Tracks with Pileup in 2011

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(C. Ruwiedel tragically died recently)

Basic strategy: validate calorimeter JES using ratio

$$R_{\text{trk}} = \langle r_{\text{trk}} \rangle = \left\langle \sum_{\text{trk}} |\vec{p}_{T,\text{trk}}| / p_{T,\text{jet}} \right\rangle$$

Track cuts  $p_T > 1 \text{ GeV}$  and  $\Delta z_0 \sin \theta < 1.5 \text{ mm}$  minimize pileup.

Use Period 2011D–G data ( $788 \text{ pb}^{-1}$ ). Concentrate on:

- In-time pileup effects: dependence on  $N_{\text{vtx}}$ .
- Out-of-time pileup effects: dependence on bunch train position.

Compare with MC10b (50 ns pileup). Apply weights when filling histograms.



# Object and Event Selection

**Trigger:** For jet stream require `EF_jX_a4tc_EFFS` passed if leading jet has  $p_{T,0} > 2X$  GeV. Use corresponding `iLumiCalc` weight.

Also use muon stream for low- $p_T$  jets.

**Tracks:** Selection similar to minbias analysis:

$$p_T > 1 \text{ GeV}, \ N_{\text{pixel}} \geq 1, \ N_{\text{SCT}} \geq 6, \ N_{\text{TRT}} > -1$$

$$d_0 < 1.5 \text{ mm}, \ z_0 \sin \theta < 1.5 \text{ mm}$$

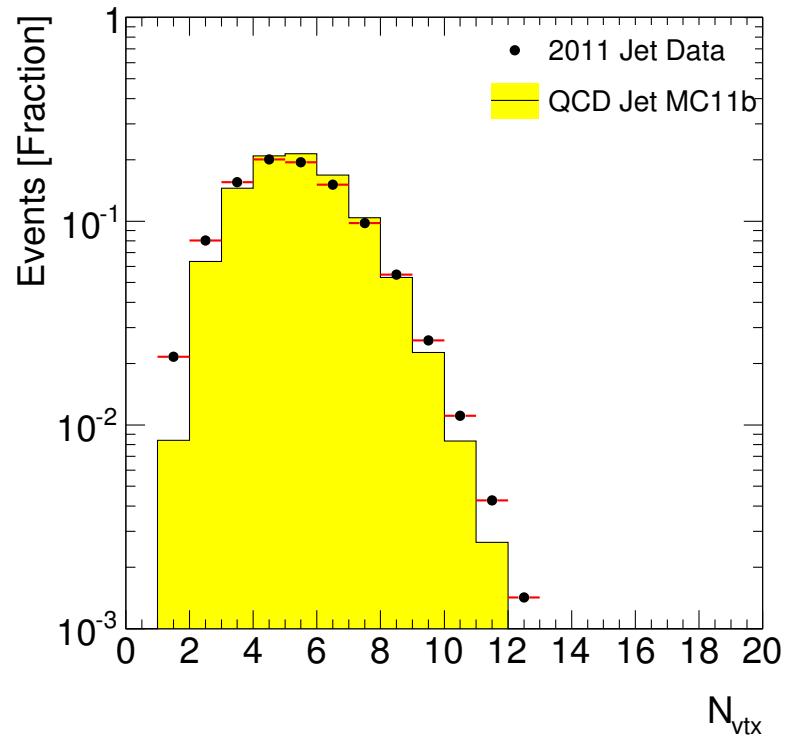
Higher  $p_T$  cut minimizes soft (non-DGLAP) tracks and ensures good tracking acceptance.

**Jets:** Apply standard cleaning cuts, rejecting “bad” jets.

For MC require event vertex match reconstructed primary vertex within  $|\Delta z| < 0.2$  mm.

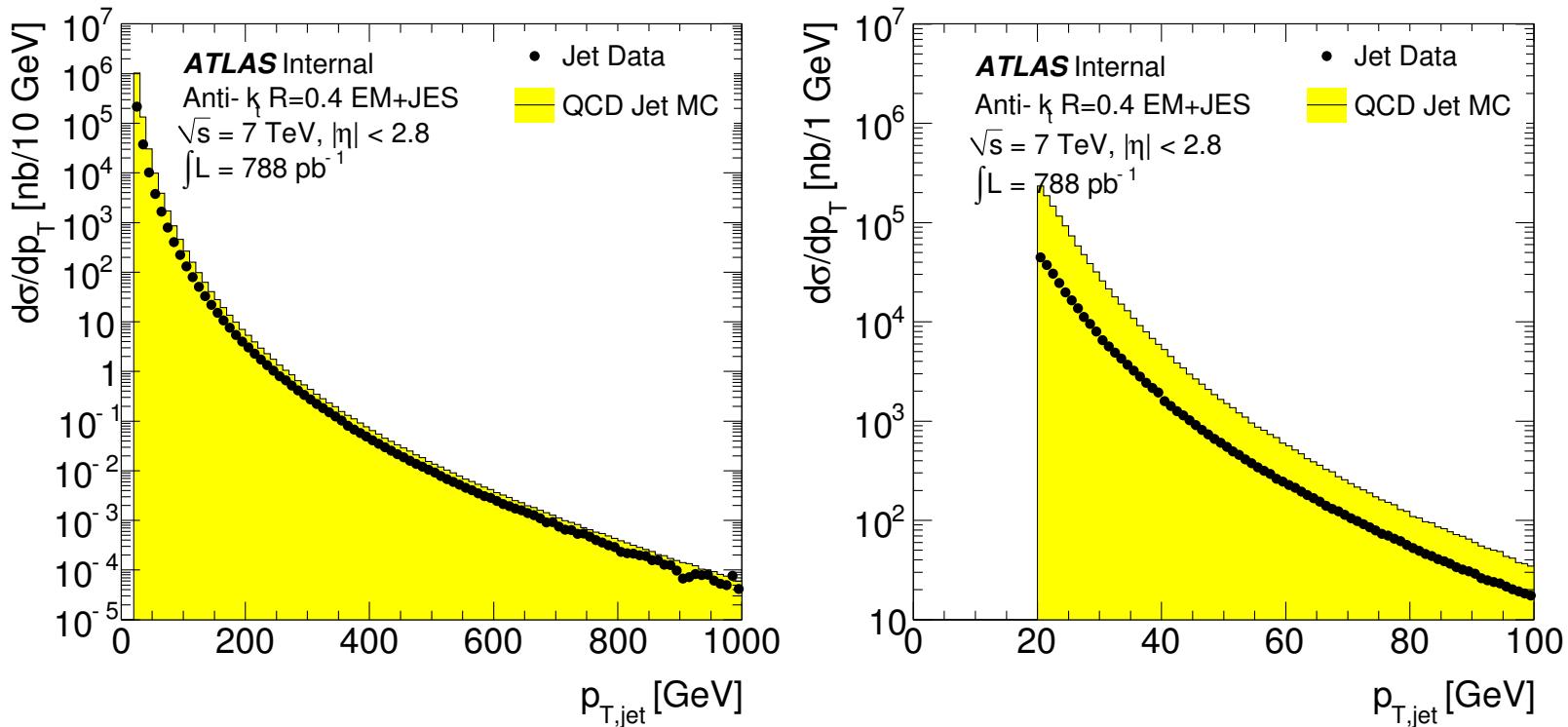


Data and MC have different pileup. Applied PileupReweighting to match  $\mu$  distributions. Reasonable agreement for  $N_{\text{vtx}}$  except for small tails:



# Global Distributions

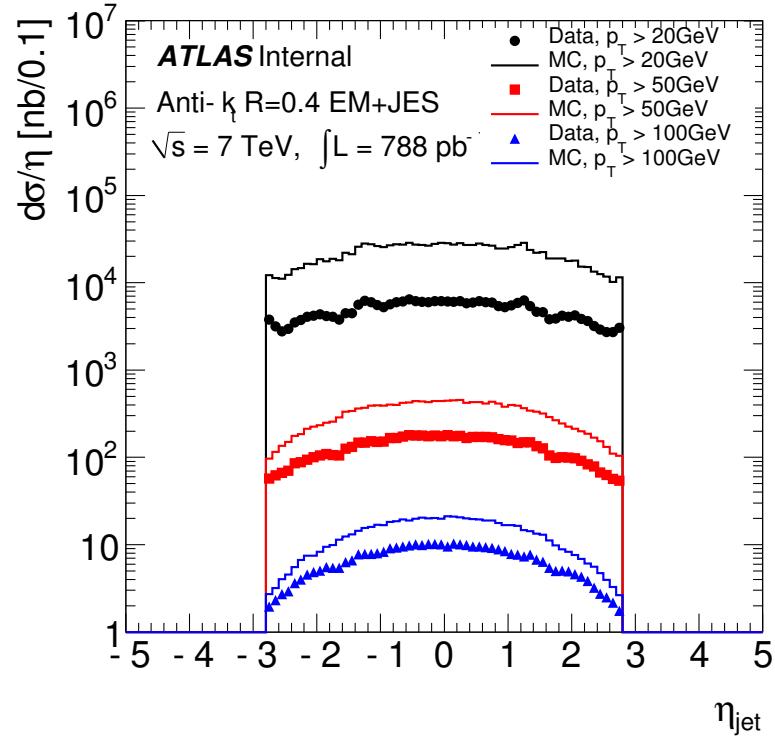
Reasonable agreement for  $p_T$  dependence between data and LO MC apart from normalization:



Structure near  $p_T \approx 1 \text{ TeV}$ ?



$\eta$  dependence flatter in data than in MC:



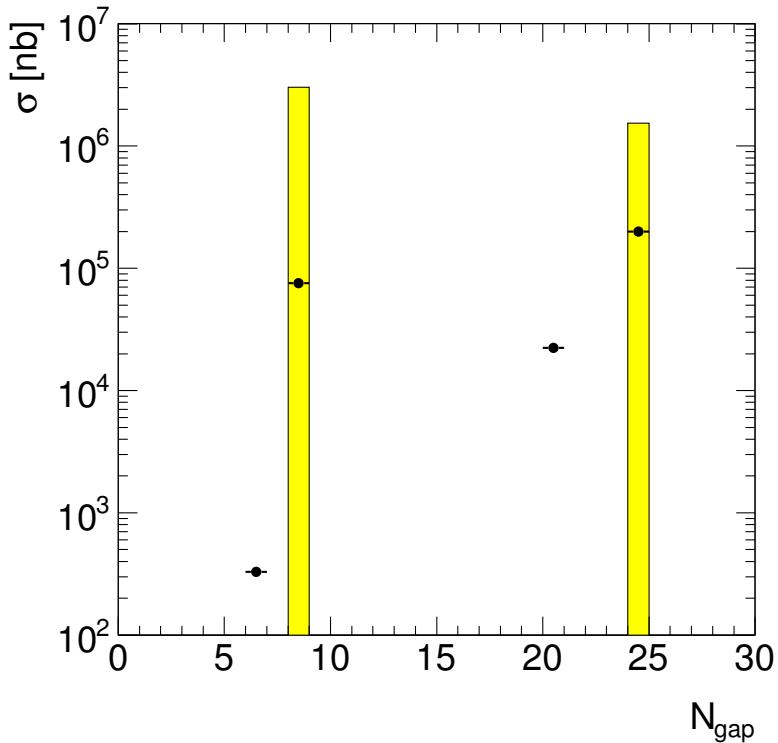
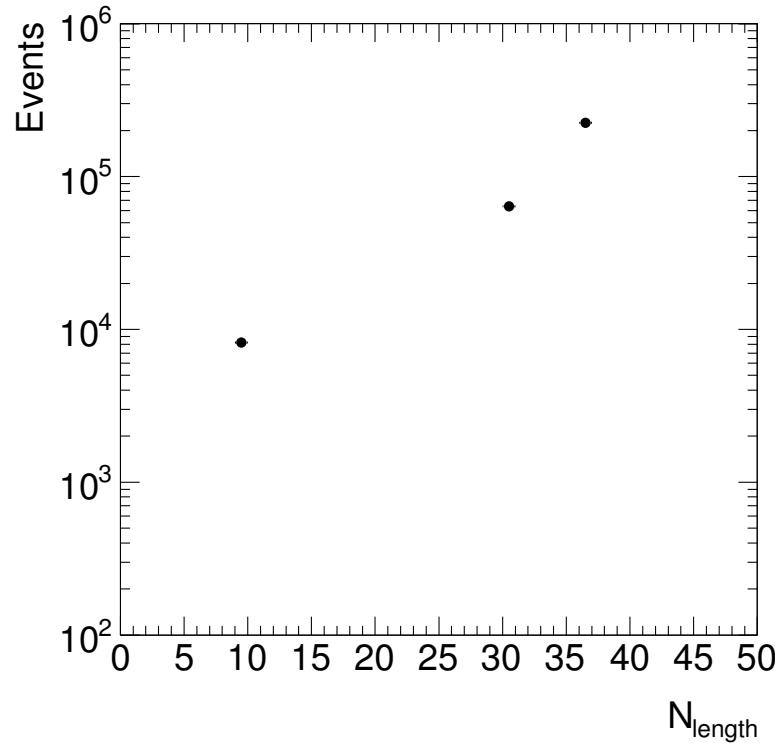
Will concentrate on central region,  $|\eta| < 1.2$ .



# Bunch Train Dependence

Most trains contain  $N_{\text{length}} = 36$  bunches, but some are shorter.

Gaps before trains contain  $N_{\text{gap}} = 8, 20$ , or  $\geq 24$  empty bunches:



MC has only two types of trains. (Later use  $N_{\text{gap}} = N_{\text{gap}} + 1$  to include first filled bunch.)

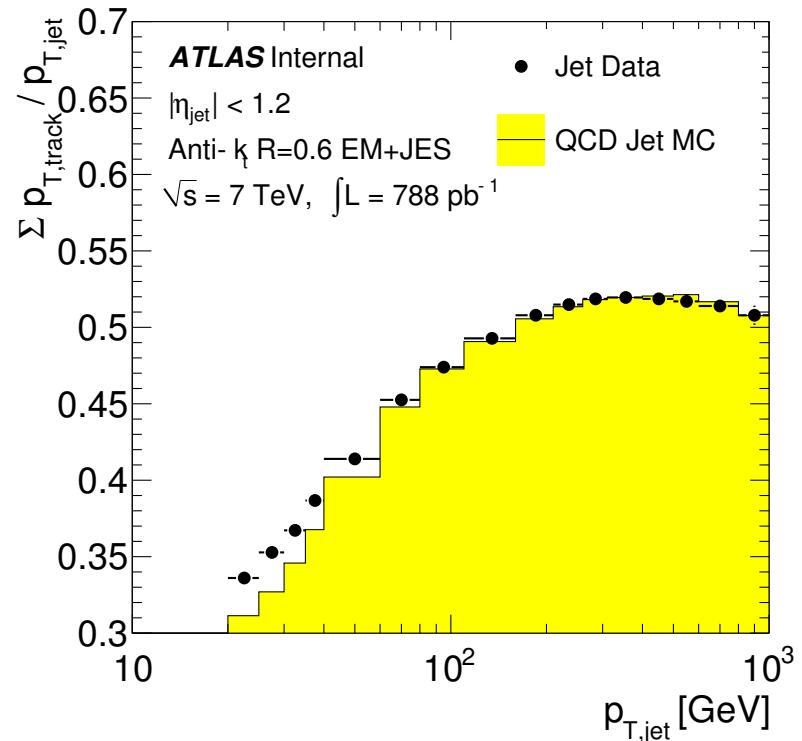
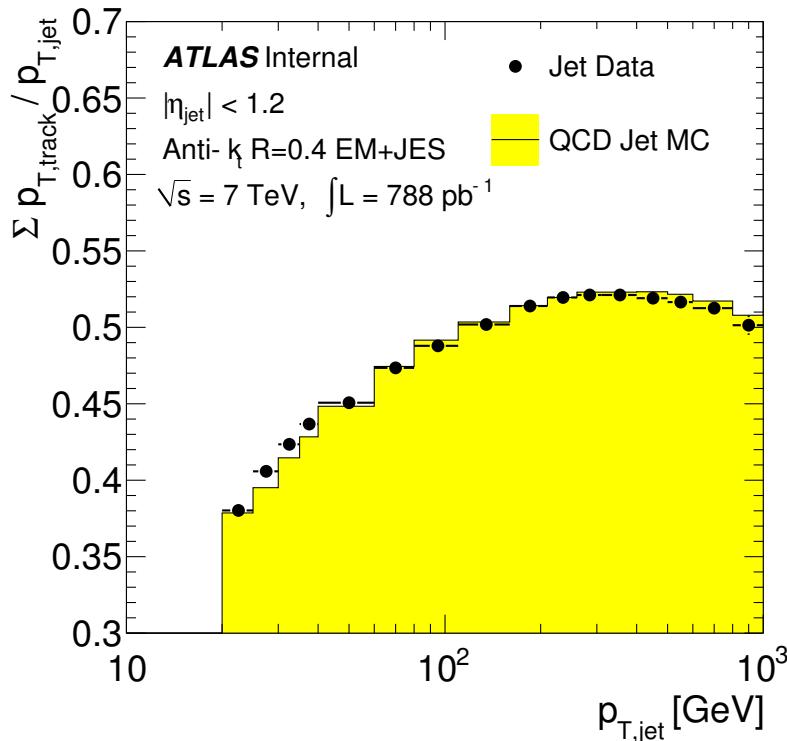


Have tried several generic variables, e.g.,  $N_{\text{front}}$ , number of filled (25 ns) bunches in front of bunch. Recall previous bunches over  $\mathcal{O}(600 \text{ ns})$  contribute negative energy.

Currently have only  $N_{\text{gap}} = 9, 21$  and  $\geq 25$ , with last two being similar. Seems better to consider each specific case.



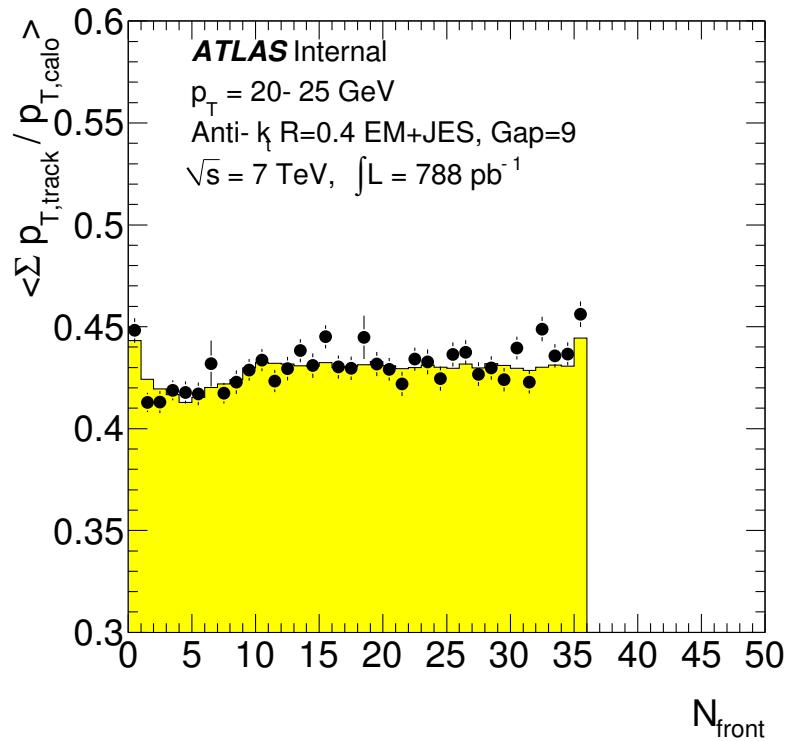
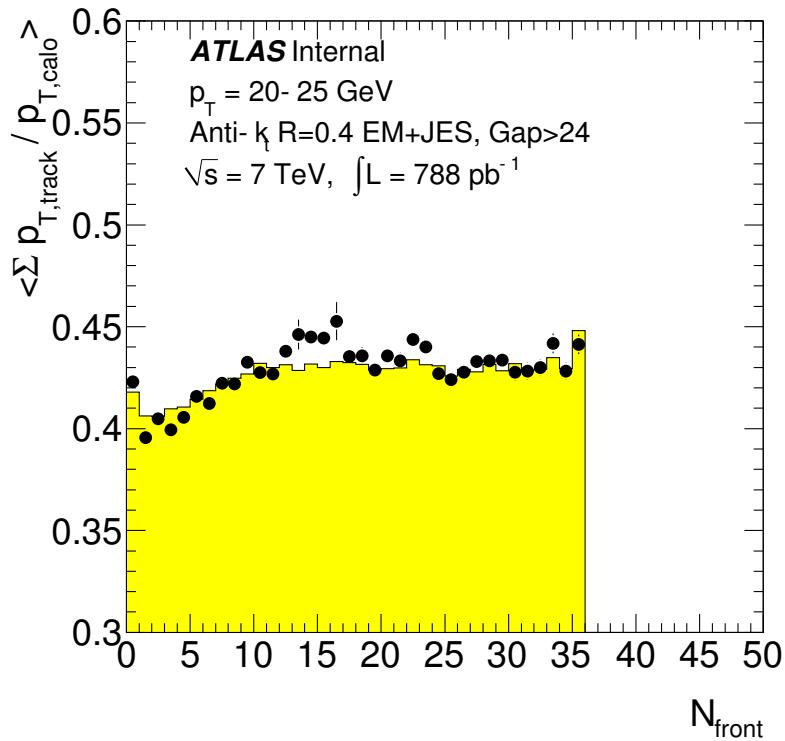
Good agreement for  $R_{\text{trk}}$  between data and MC11b:



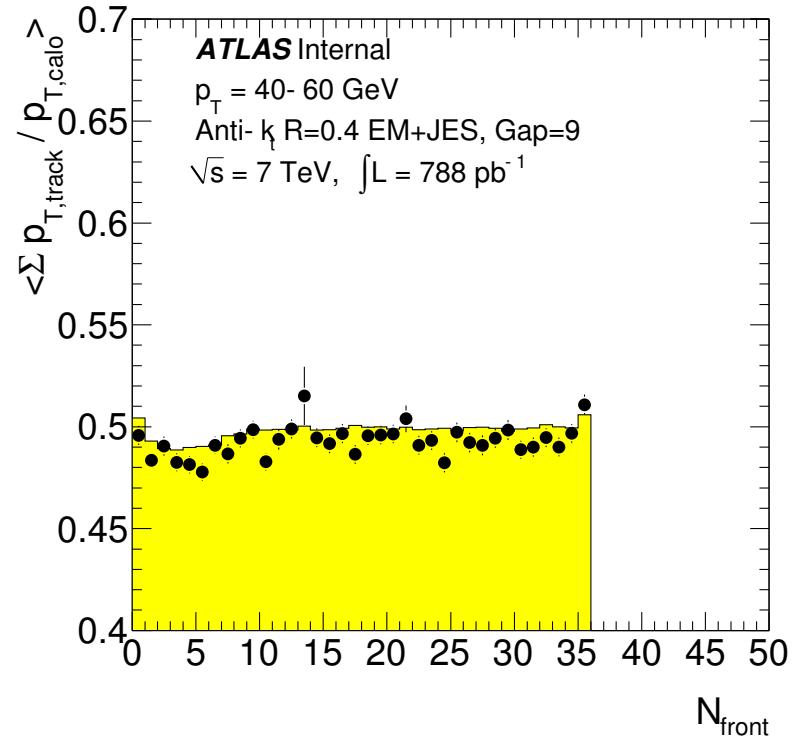
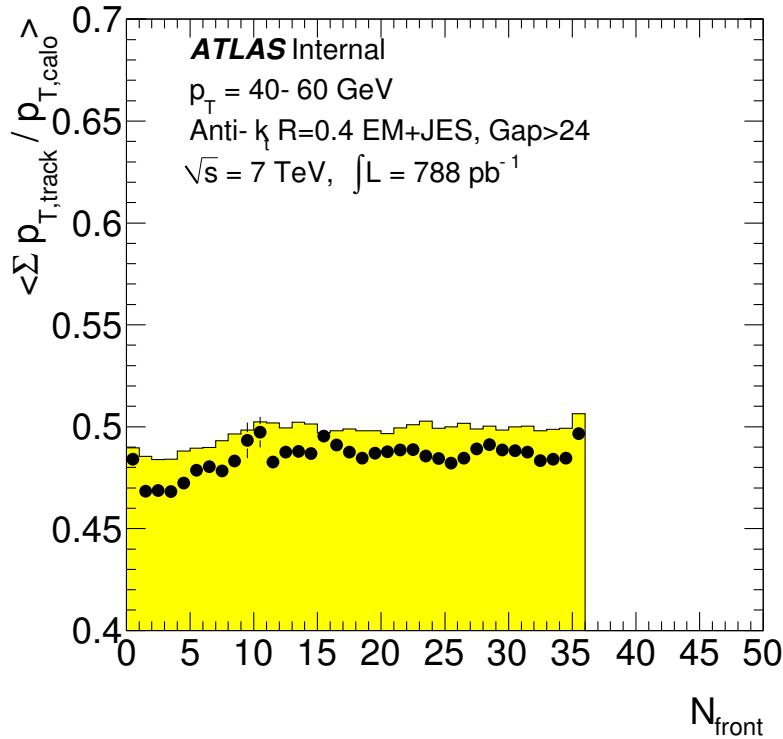
But some differences for  $R = 0.6$  at low  $p_T$ .



Profile plots for  $p_T = 20$  GeV with large and small gaps:



Profile becomes fairly flat for  $p_T \gtrsim 40$  GeV:



Complete plots in backup.



## $N_{\text{vtx}}$ Dependence

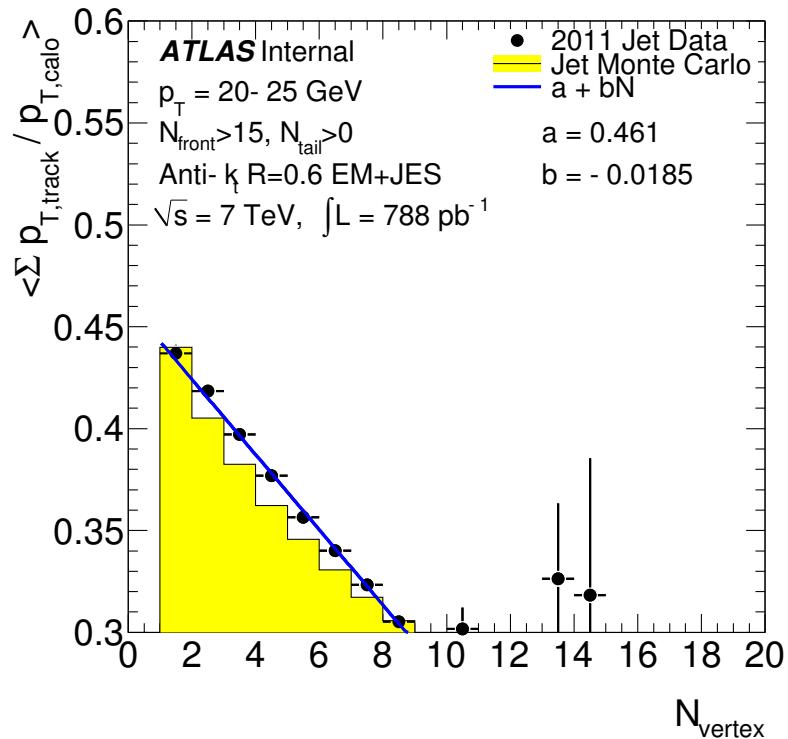
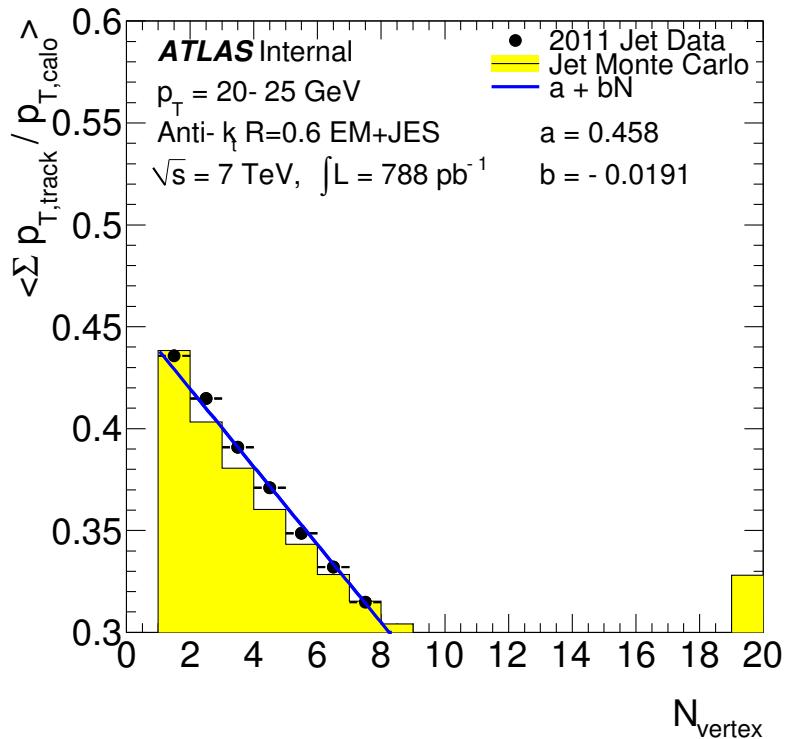
$N_{\text{vtx}}$  provides measurement of in-time pileup. More pileup increases  $E_T$  and so decreases  $R_{\text{trk}}$ .

Observe linear dependence on  $N_{\text{vtx}}$  at least for moderate values.

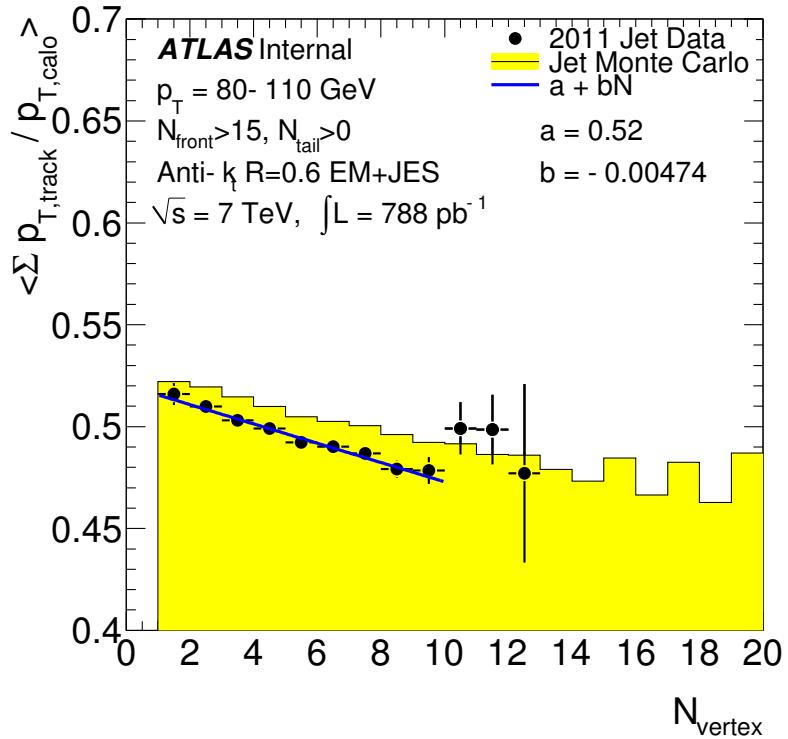
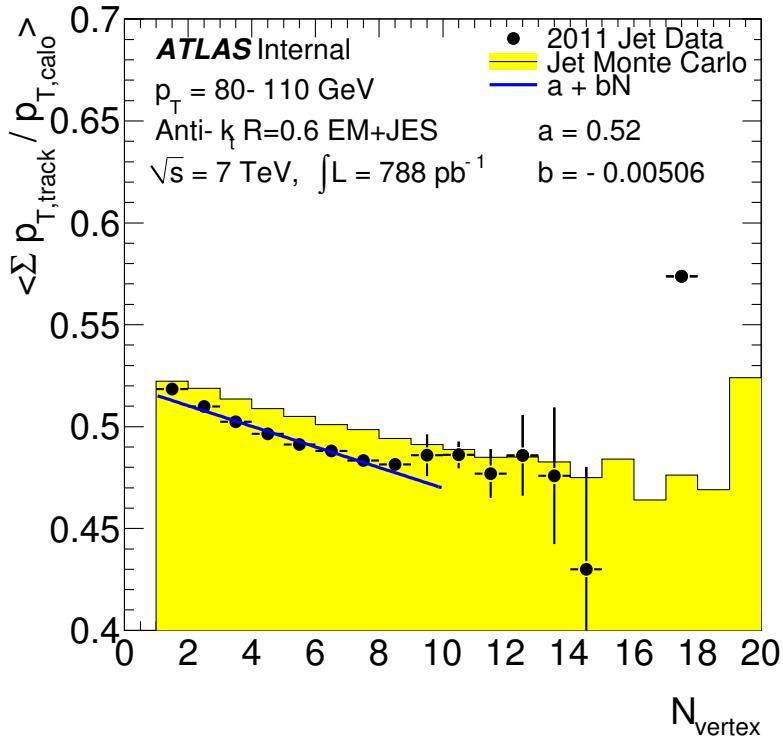
Plot distributions both for full train and for BCID plateau. Slopes are similar  $\Rightarrow$  can treat out-of-time and in-time pileup approximately independently.



$N_{\text{vtx}}$  dependence for  $p_T = 20\text{-}25 \text{ GeV}$ :



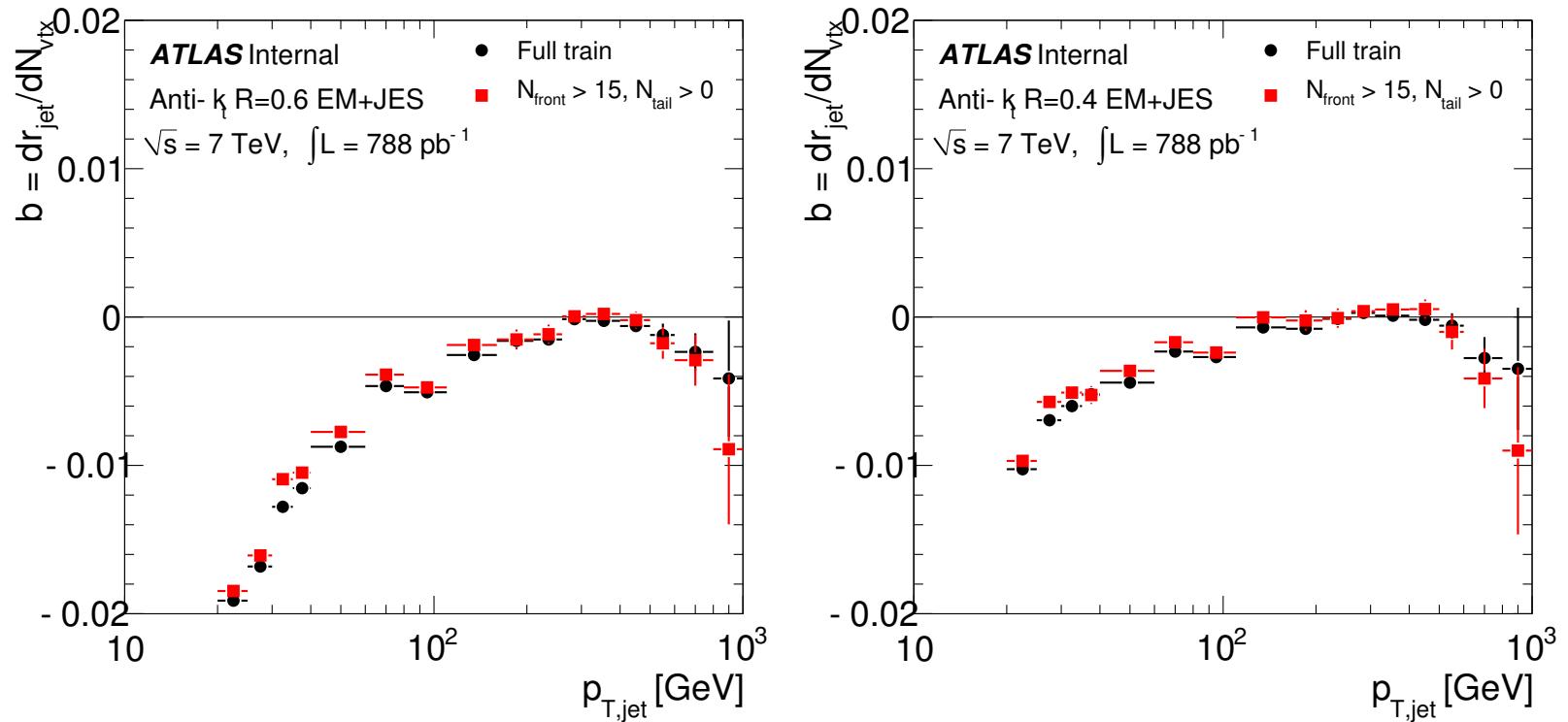
Same for  $p_T = 80\text{-}110\text{ GeV}$ :



Complete plots in backup.



Dependence on  $N_{\text{vtx}}$  has weak dependence on bunch train position:



Differences are statistically significant but small compared to  $p_T$  dependence.



## Results from Muon Stream

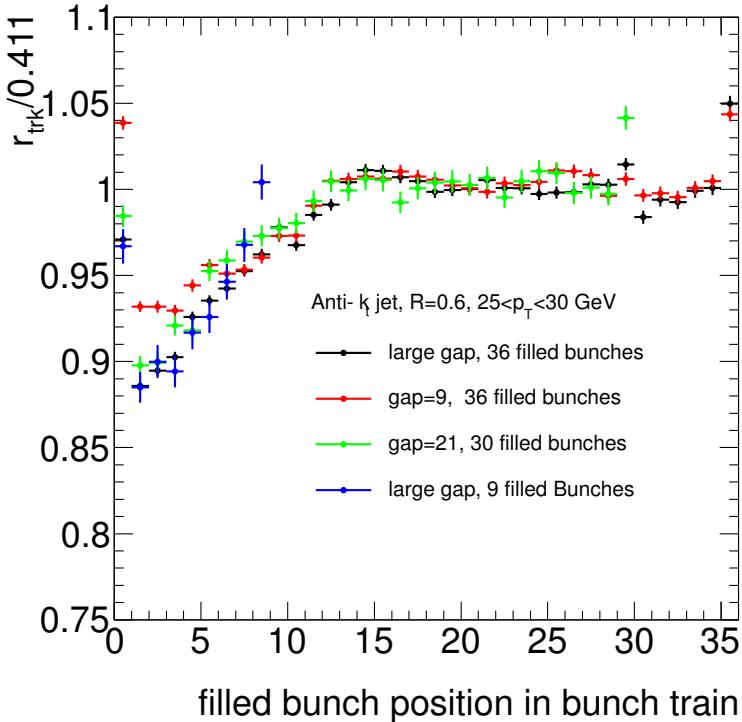
Muon stream has 4–5 times statistics at low  $p_T$  and less bias.

Can compare data samples with various bunch train selections.

Muon statistics for jet samples are much too small. Can compare jets with isolated muons and  $W \rightarrow \mu\nu$  Monte Carlo samples.



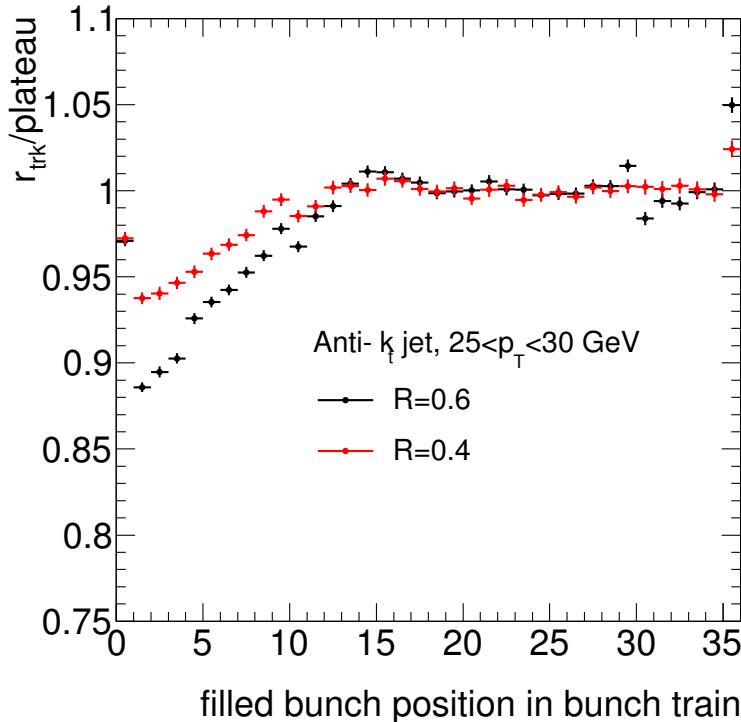
Muon-triggered  $R_{\text{trk}}$  for various bunch-stream samples:



Jets at front of trains have less negative pileup  $\Rightarrow$  higher  $p_T \Rightarrow$  lower  $R_{\text{trk}}$ . Last bunch has no trailing  $p_T \Rightarrow$  lower  $p_T$ . Results (qualitatively) understood.



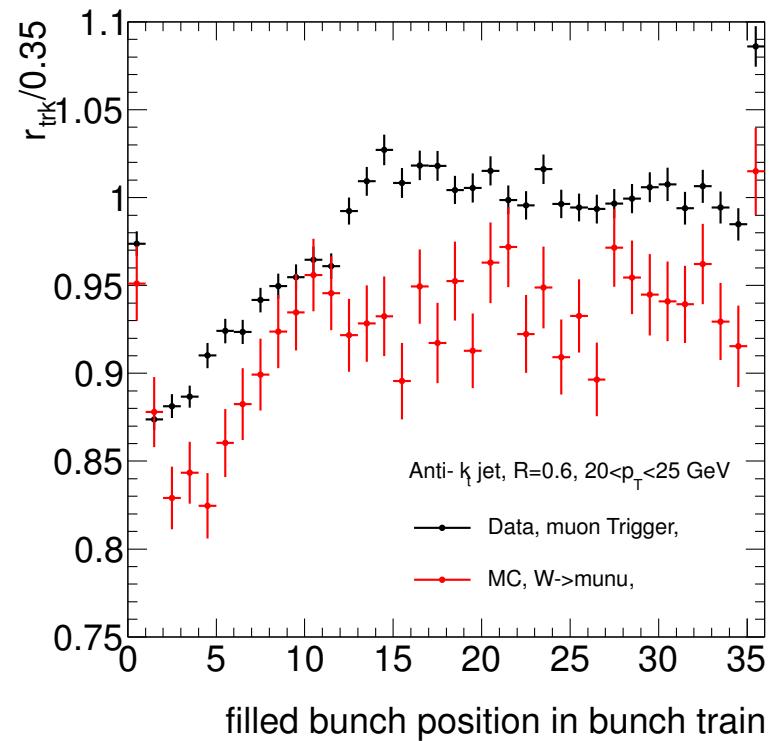
Pileup scales with jet-area  $\propto R^2$ :



Seems consistent with observed shifts.



Compare jets with isolated  $\mu$  and  $W \rightarrow \mu\nu$  Monte Carlo. Find qualitatively similar dependence:



# Summary

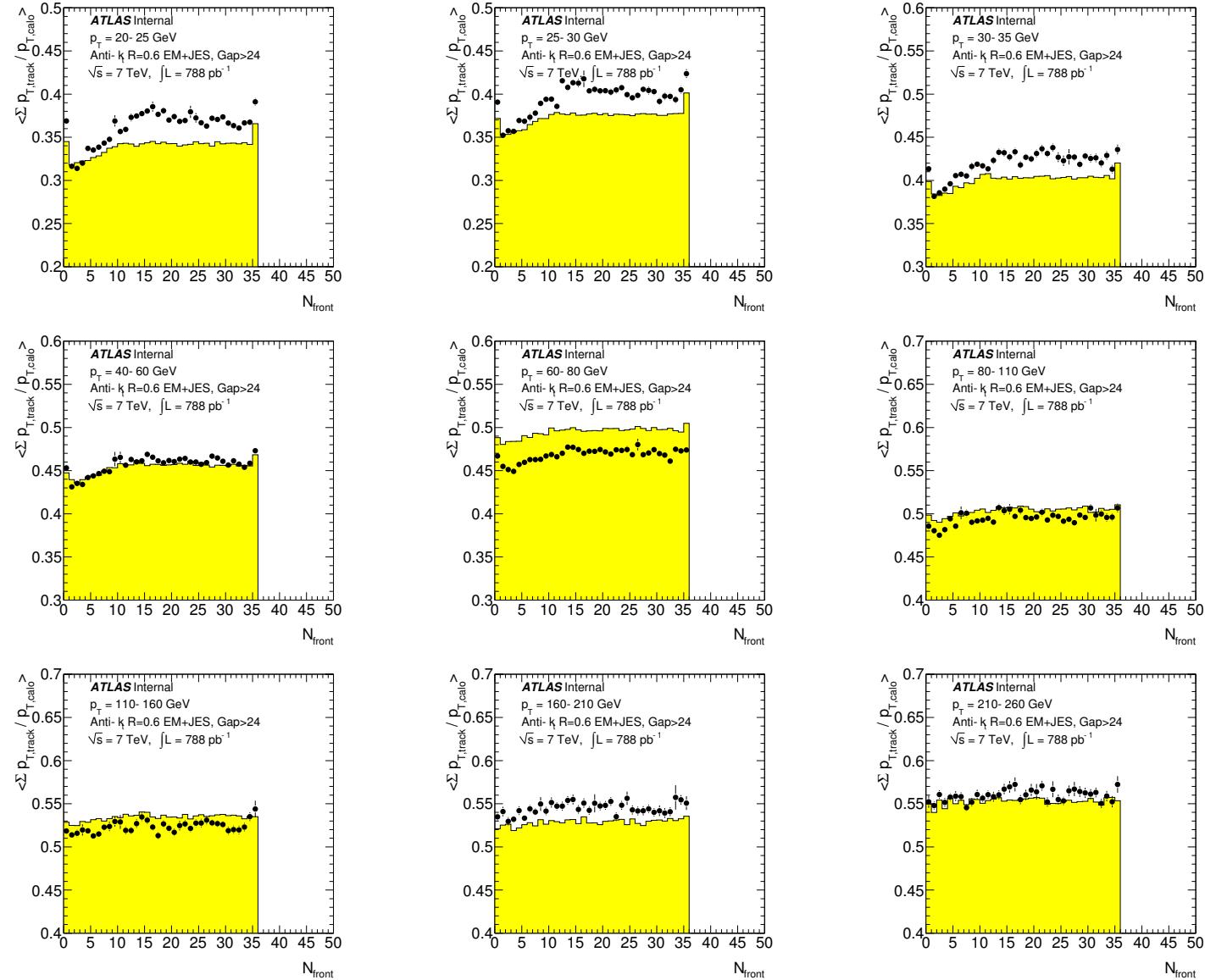
Will propose public performance plots selected from above. . . .



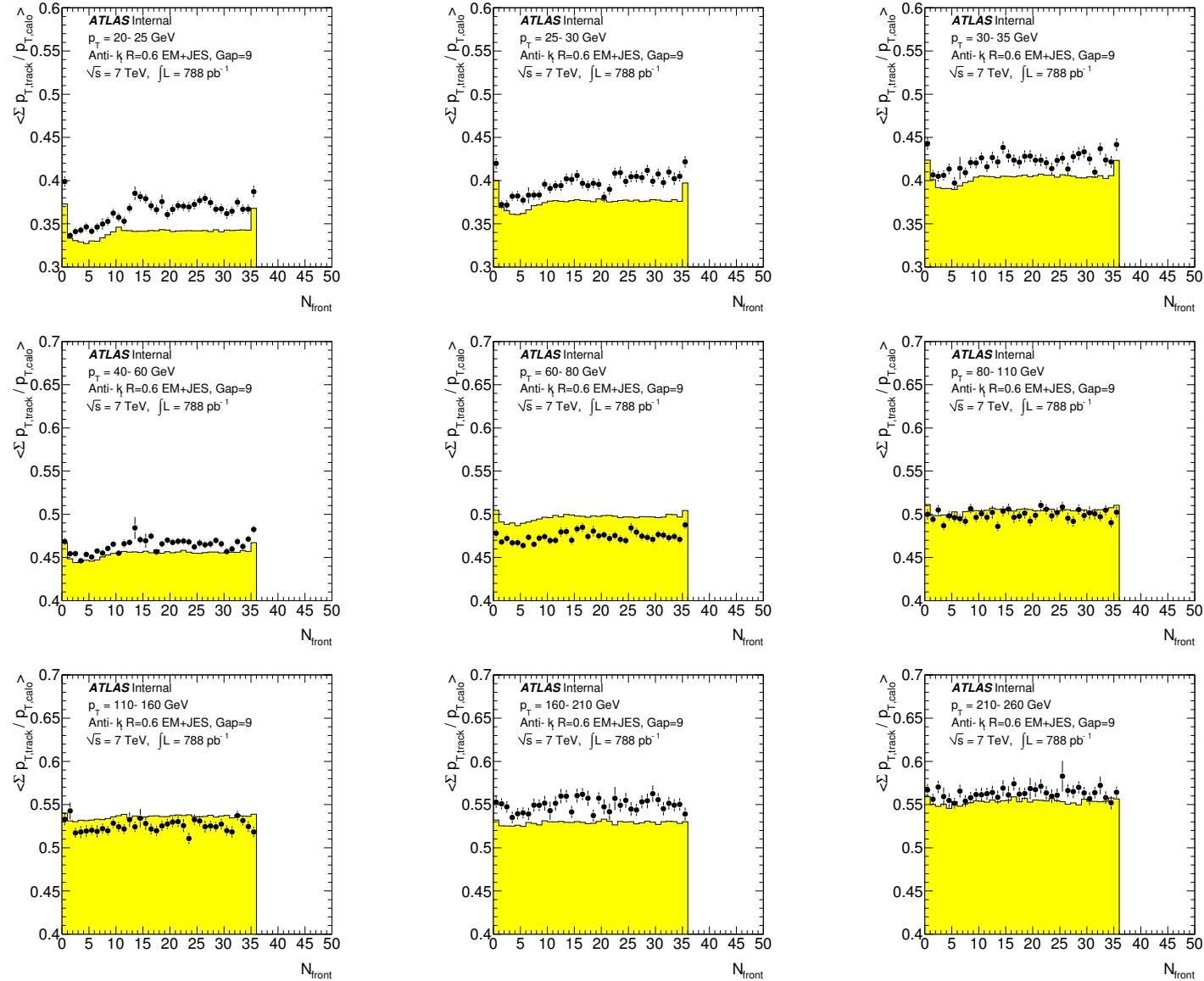
# Backup



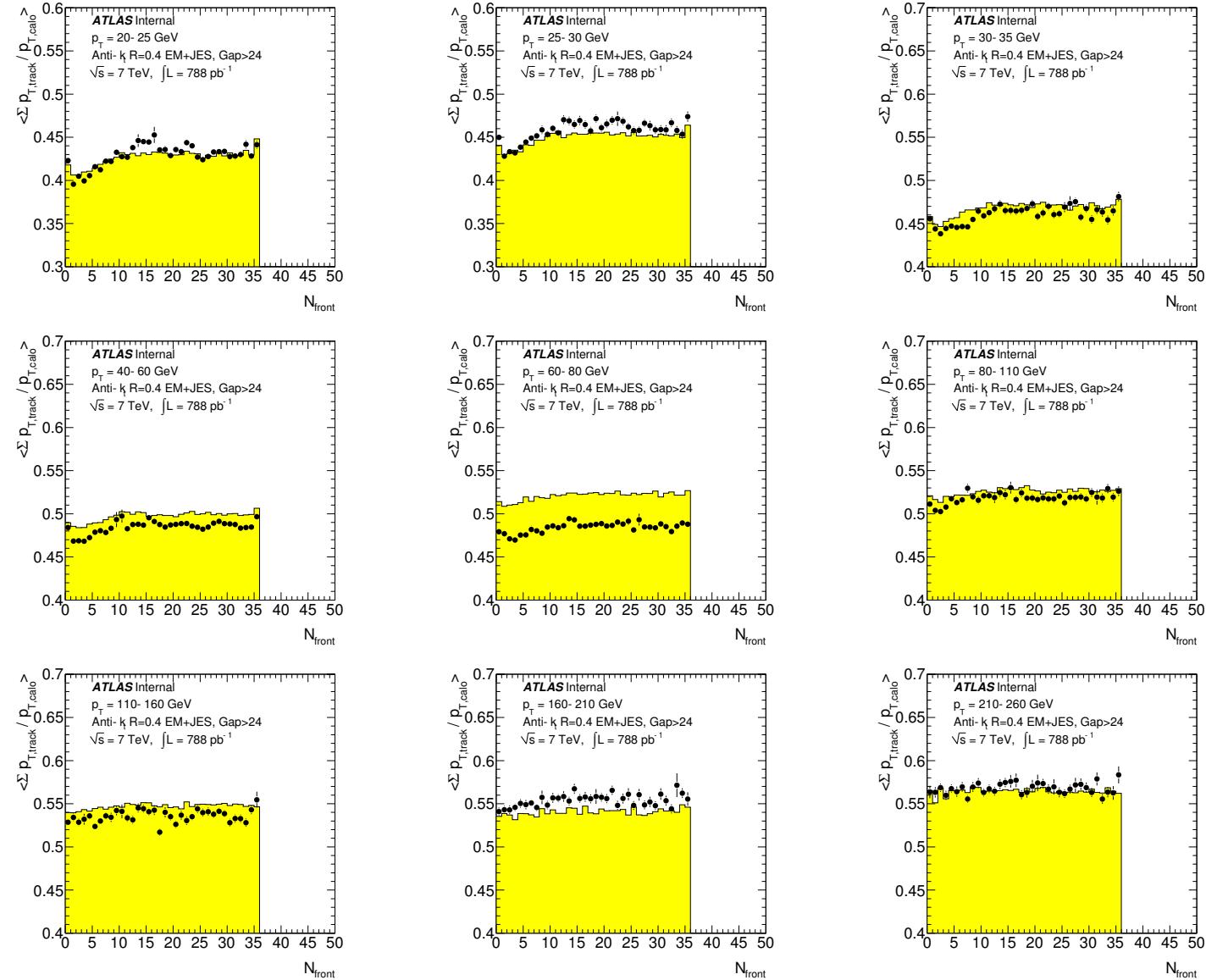
# $N_{\text{front}}$ profile plots for $R = 0.6$ EM+JES with large gaps:



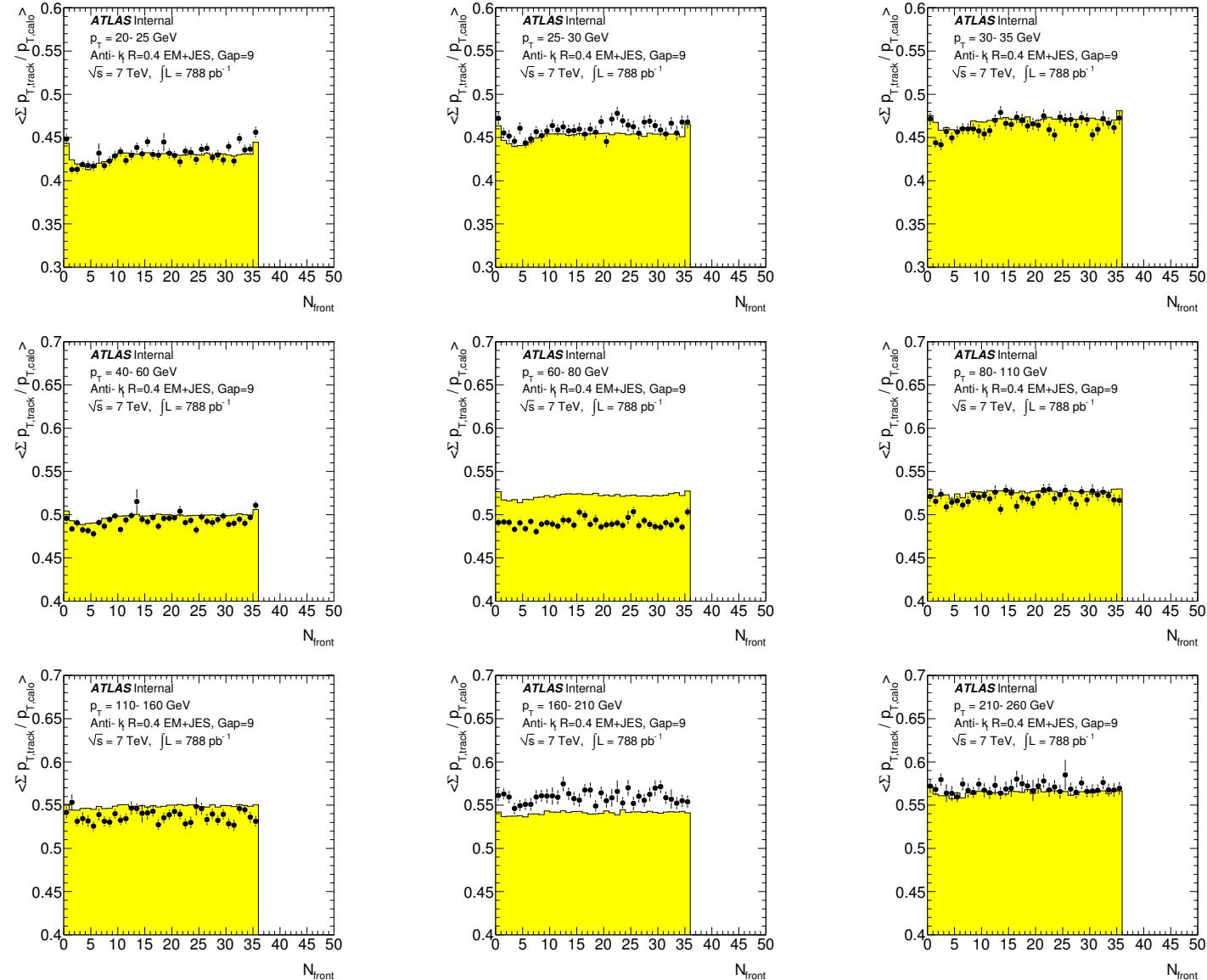
# $N_{\text{front}}$ profile plots for $R = 0.6$ EM+JES with small gaps:



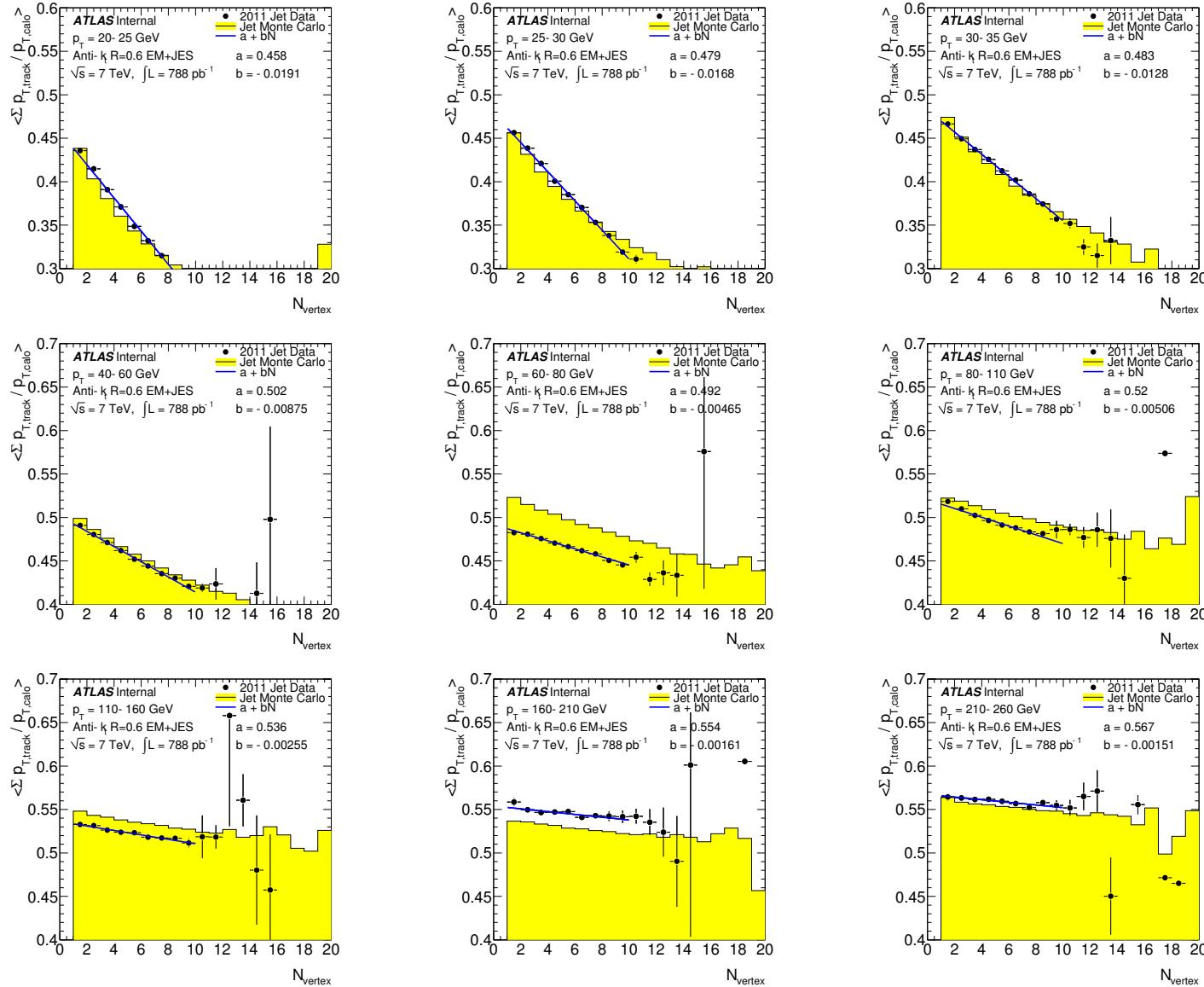
# $N_{\text{front}}$ profile plots for $R = 0.4$ EM+JES with large gaps:



# $N_{\text{front}}$ profile plots for $R = 0.4$ EM+JES with small gaps:



$N_{\text{vtx}}$  profile plots for  $R = 0.6$  EM+JES in  $p_T$  bins:



# $N_{\text{vtx}}$ profile plots for $R = 0.4$ EM+JES in $p_T$ bins:

